2010 Summer school

Assessing Climate Change

July 12th: Carbon accounting at LSCE

INTRODUCTION

The exchange of carbon, nitrogen, oxygen, hydrogen, … between the earth system components defines the different biogeochemical cycles. Extracted from the IPCC chapter 7, one can read: "*Biogeochemical cycles interact with the climate system over a wide-range of temporal and spatial scales. Nonlinear interactions involving physical, chemical and biological processes could amplify (positive feedbacks) or attenuate (negative feedbacks) the disturbances produced by human activities. The response of the climate system to anthropogenic perturbations is therefore expected to involve reciprocal interactions with the land surface, the carbon cycle, reactive gases and aerosol particles.*"

Carbon cycle is one major biogeochemical cycle. It is part of the climate problem as the main driver of the increasing radiative forcing due to carbon emissions related to human activities. It is part of the solution as natural ecosystems have been offering us a 50% discount on climate change by absorbing about half of the anthropogenic emissions of CO_2 for decades (carbon sinks). Limiting our emissions and preserving (or developing) the carbon sinks on the long terme are two complementary approaches to address the carbon cycle issues in the context of a changing climate.

Carbon accounting is the action of providing estimates/verifications of the carbon fluxes between the relevant reservoirs of present carbon cycle: oceans, land surfaces, and atmosphere, in order to perform carbon budgets. This can be achieved by various methods. Bottom-up methods mainly rely on economic data or energy statistics for anthropogenic fluxes (e.g. fossil fuel use related CO2 emissions), on process-based model for natural fluxes (e.g. vegetation model), and on local direct flux measurements. Atmospheric observations of the concentrations of greenhouse gases (GHG) can provide an integrated top-down view of their sources and sinks if one can invert the origin of the measured air masses. This is the so-called inversion approach. So far, carbon accounting is mainly performed for anthropogenic emissions using bottom-up inventories typically every year or less, as constrained by international and national policies. They rely on declaration of industrials, or state agencies and no independent method is yet available at political level.

Bottom-up and top-down approaches can be developed at various spatial scales: agglomerations or large industrial sites (1-10^3 km^2), political or natural regions (10^4-10^5 km^2), country to European scale (10^5-10^7 km^2), and global scale. The actors, the constrains, the requested observations, and the analysis methods generally differ for each scale: the data requirements for a mayor to implement a local CO2 budget for a climate plan will not require the same strategy than the CO2 accounting of all France, although the integration of all local

climate plans should be consistent at the end with the total French emissions of CO_2.

As should appear this day, we are really at the beginning of the story of carbon products. Scientists will be more and more able to produce GHG flux estimates at relevant scales for some potential end users (industrials, state agencies, insurances, carbon markets, policy makers, large agglomerations, agriculture, …), but the real products, directly usable by the end user are not there yet. More, some users still need to define their sensitivity to climate change and what kind of products they would need to estimate this risk. The link between scientists and end users is still to be built. As international or national constrains will increase in the future, consistent with policies for climate change mitigation, one can anticipate that the pressure on designing carbon products will increase in the next decades, with probably a critical position in the decision chain. Your generation has to create the link and the carbon products, and this is a great challenge in front of you.

OBJECTIVE OF THE SESSION

In this ACC session, we propose you to contribute addressing the following question:

What can we learn from atmospheric observations to estimate/verify carbon fluxes at various scales?

To do so, the session is divided into three parts:

- Inputs on the carbon cycle, on ICOS (Integrated Carbon Observing System), on local to global external constraints, and on CARBOCOUNT KIC project (~1h30)
- Creative thinking in five groups in order to define ideas/products/systems addressing the issue of carbon accounting at a given scale (1 spatial scale per group, ~1h30)
- Short restitution of each group and promotion of ideas/products/systems (~45') during/before lunch break (sandwiches).

More precisely, after the talks, 3 to 5 groups will be formed during the coffee break around the proposed scales of interest:

-Agglomeration (urban environment)
-Rural region with forests
-France/Europe
-World

Then, each group will have about 1h30 to discuss and propose ideas/products/systems on the use of atmospheric measurements to estimate/verify carbon fluxes at this scale. In order

to guide this attempt of creative thinking:

- Questions have been formulated in the following guidelines.
- "Experts" will be available during the group work to help defining and positioning the ideas on: GHG observations, models, industrial needs, ecosystems, ICOS products. As in "real life", members of the group can consult them when necessary in their thinking. Groups have to organize themselves to spread the work
- Each group will have an access to internet.
- The ICOS laboratory will be presented to each group during 15 minutes.

At 12h30, each group briefly presents its ideas/products/systems in 5' and a maximum of 3 slides.

GUIDELINES FOR THE GROUP WORK:

Using atmospheric observations to verify carbon emissions at various scales; agglomeration, rural regions with forests, France/Europe, World.

What are the existing scientific products at this scale?

Who are the current users and what do we know about their requirements?

Who are the likely users in the future? New markets?

How is legislation likely to evolve at this level?

What are the gaps between scientific products and user needs?

How would you improve existing products to increase benefit to users?

What new products should be developed?

Imagine how emission attribution (e.g. anthropogenic versus natural) might be incorporated into product.

TIMELINE

9h: Welcome

9h-10h30: An introduction to Carbon cycle, external constrains and existing projects (talks & questions)

Carbon cycle basics

External constraints on the carbon cycle

ICOS : Integrated Carbon Observing System

Carbocount: a project submitted to Climate-KIC on carbon accounting

10h30-10h45: coffee break and group formation around one spatial scale (agglomeration, Rural region with forest, France/Europe, Global).

11h15-12h45: creative thinking in 3 to 5 groups.
Experts on different topics will be available to discuss and answer questions from the groups during the group work, and help them designing their idea/product/system.

12h30-13h15: short restitution of the groups during lunch (sandwiches)

13h30: departure for Cité Universitaire

FOLLOWING : PDF OF THE TALKS

ANNEX 1: A NEW ORDER OF MAGNITUDES ABOUT CARBON CYCLE

PHENOMENON	**CO_2**	**CH_4**
Mean surface value	385 ppm	1780 ppb
North-South changes	3 ppm	150 ppb
Local changes close to emissions	Up to 200 ppm	Up to 500 ppb
Seasonal cycles (max)	20 ppm	80 ppb
Lifetime in the atmosphere	> century	10 years
Typical measurement precision (in-situ)	<0.2 ppm	3-5 ppb
Typical satellite data precision	1-3% (3-10 ppm)	2% (35 ppb)
Targeted measurement precision (in-situ)	<0.1 ppm	2 ppb
Targeted satellite data precision	1% (4 ppm)	1% (18 ppb)
1 Gt CO2 emitted gives globally:	0.5 ppm	
1 Tg CH4 emitted gives globally:		0.3 ppb
2008 total emission	10 GtC	550 TgCH4
CO2 emission for 1km by car	50-200g	
CO2 emission for 1km by train	3g/person	
Heating of a house for 1 year (fuel)	2.5 tC	
Heating of a house for 1 year (nat. gas)	2 tC	
Heating of a house for 1 year (electricity)	0.6 tC (France, Nuclear 80%) 4tC (UK, fuel prod.)	

ANNEX 2: Main conclusions of the IPCC 2007 report (group1) on biogeochemical cycles (extracted from chapter 7) :

The Land Surface and Climate

- Changes in the land surface (vegetation, soils, water) resulting from human activities can significantly affect regional and local climate through shifts in radiation, cloudiness, and surface temperatures. Similarly, Changes in land use, climate, and atmospheric composition affect the distribution and functioning of terrestrial ecosystems.
- Changes in vegetation cover have a substantial effect on surface energy and water balance at the regional scale. Model results indicate increased boreal forest cover results in reduced albedo and significant regional warming, offsetting cooling effects of carbon uptake.
- The impact of land-use change on climate may be very significant at regional scales, but is expected to be small at the global scale in comparison with greenhouse gas warming.

The Carbon Cycle and Climate

- The land and oceans have continued to absorb ~45% of the CO_2 emissions from fossil fuel burning and cement production. This fraction was lower in the 1980's (0.39), higher in the 1990's (0.50) and recovered an intermediate value during 2000–2005 (0.41). There are no indications of a trend in the fraction of emissions that are absorbed by the land and ocean combined since 1958, which suggests that large non-linear feedbacks between climate and the carbon cycle have not yet taken place.
- The fraction of emissions taken up by the oceans appear to have decreased from 0.42 ± 0.07 for the period 1750–1994 to 0.37 ± 0.07 for the period 1980–2005, consistent with the limited rate at which CO_2 is transported from the surface to the deep ocean. This trend are expected to continue.
- A combination of techniques gives an estimate of the flux of CO_2 to the atmosphere from land use change of 1.6 (0.5 to 2.8) GtC yr^{-1} for the 1990's. A revision of the TAR estimate for the 1980s downwards to 1.3 (0.3 to 2.8) GtC yr^{-1} suggests little change between the 1980s and 1990s, and continuing uncertainty in the estimates.
- Interannual variability in the growth-rate of atmospheric CO_2 is dominated by the response of land carbon to climate variations. Large decadal changes are observed in the land-atmosphere CO_2 flux, with estimates of –0.2 ± 0.7, –1.4 ± 0.7, and –0.7 ± 0.7 GtC yr^{-1} for the 1980's, 1990's and 2000-2005 time periods, respectively. This decadal variability also appears caused by the response of land carbon to climate variations.

- Although the ocean is currently absorbing large amounts of CO_2 (~2 GtC yr^{-1}), its uptake capacity will decrease with rising CO_2. After the ocean equilibrates with the atmosphere (on timescales of centuries), one quarter of the anthropogenic CO_2 will remain in the atmosphere, eventually to be neutralized by carbonate and silicate weathering reactions in the ocean. Roughly one quarter of anthropogenic CO_2 will influence climate for thousands to hundreds of thousands of years.
- Increasing CO_2 concentrations in the ocean has lowered the pH (increasing the acidity) by 0.1 since 1750. The consequences for the carbon cycle include the reduced calcification by marine organisms and the dissolution of shallow-water sediments. The net effect is unknown.
- Coupled climate-carbon cycle models indicate that climate change will increase the fraction of anthropogenic CO_2 that remains in the atmosphere. This positive climate-carbon cycle feedback leads to an additional increase in atmospheric CO_2 concentration of 20 to 220 ppm by 2100, under the SRES A2 emissions scenario
- The largest contribution to the uncertainty in the climate-carbon cycle feedback concerns the response of vegetation and soil to climate change.

Reactive Gases and Climate

- Atmospheric CH_4 is dominated at present by anthropogenic sources. Since there is no general consensus on significant change in CH_4 sinks since the TAR, the recent slow down in growth rate of atmospheric concentration is likely due to changes in sources strengths.
- Most models predict that climate change affects methane emissions from wetlands. Emissions likely increase in warmer and wetter climate and decrease in warmer and dryer climate. However, this has not yet been confirmed by field observation.
- About 50% of current sources of atmospheric N_2O result from human activities – animal husbandry, fertilizer and crops, and coastal oceans being the three largest sources. Emissions from the coastal oceans represent ~20% of the 'anthropogenic' sources and result mainly from increasing anoxic conditions in or above the sediments.
- New model estimates of the global tropospheric ozone budget suggest that input of ozone from the stratosphere (approximately 500 Tg yr^{-1}) is smaller than estimated in the TAR (770 Tg yr^{-1}), while the photochemical production and destruction rates (both approximately 4500 Tg yr^{-1}) are higher than estimated by TAR (3500 Tg yr^{-1}).
- Future climate change is expected to cause a decrease in background tropospheric ozone

(due to higher water vapor) but increases in regional ozone pollution (due to higher temperatures and weaker circulation)..

- Long-term trends in the tropospheric concentration of OH, and hence in the oxidizing capacity of the atmosphere are determined by changes in the concentrations of hydrocarbons, carbon monoxide, nitrogen oxides, water vapor, and ozone. The changes partially offset one another so that future methane lifetime remains relatively unchanged during the next few decades. On shorter time scales, the variability of the CH_4 growth rate is partially explained by the interannual variability of OH.
- There is potential for significant air quality degradation under all IPCC SRES emission scenarios. In addition to changing emissions, the resulting climate change modifies the dispersion rate of pollutants, the chemical environment for ozone and aerosol generation, and the strength of emissions from the biosphere, fires, and dust. The sign and magnitude of the effect of climate change are highly uncertain, and may vary greatly depending on region.

Aerosol Particles and Climate

- Aerosols affect the radiative fluxes by scattering and absorbing solar radiation (direct effect, see Chapter 2). They also interact with clouds and the hydrological cycle by acting as cloud condensation nuclei (CCN) and ice nuclei. A larger number of CCN increases cloud albedo (indirect cloud albedo effect) and reduces the precipitation efficiency (indirect cloud lifetime effect), both of which are likely to result in a reduction of the global, annual-mean net radiation at the top of the atmosphere. However, these effects may be partly offset by evaporation of cloud droplets due to absorbing aerosols (semi-direct effect) and by more ice nuclei (glaciation effect).
- The reduction in the global annual mean top-of-the-atmosphere net radiation as a response to the sum of these aerosol effects (direct, semi-direct and indirect cloud albedo and lifetime effect) since pre-industrial times amounts to between –0.2 and –2.3 W m^{-2} as deduced from several climate models. The highest estimated value of the sum of these effects has been reduced from more than –4 W m^{-2} in TAR to –2.3 W m^{-2} because of improvements in cloud parameterizations. Large uncertainties, however, remain, because of interactions within the climate system and feedbacks on clouds, large-scale dynamics and the hydrological cycle.
- The magnitude of the indirect aerosol effect on precipitation is even more uncertain, with model results ranging from an increase of +0.005 mm/d to a decrease of 0.13 mm/d. The decreases in precipitation are larger, when the atmospheric GCMs are coupled to mixed-layer ocean models where the sea surface temperature and, hence, the evaporation is

allowed to vary.

- Nutrients deposited with dust particles enhance photosynthetic carbon fixation in nutrient-poor regions of the oceans and land. Iron fertilisation of the ocean through dust from desert sources is one of the key drivers of reduction in glacial-interglacial CO_2 concentrations. Climate change is likely to affect dust sources more than land use change in the future.
- Since TAR, advances have been made to link the marine and terrestrial biosphere via the aerosol cycle with the climate system. Vegetation emits organic compounds. These emissions are expected to increase in a warmer climate. In addition, recent studies show that the marine biosphere may also be a source for organic aerosols.

ANNEX 3: A nature article on GHG emissions

ANNEX 4: The French "Grenelle de l'environnement"